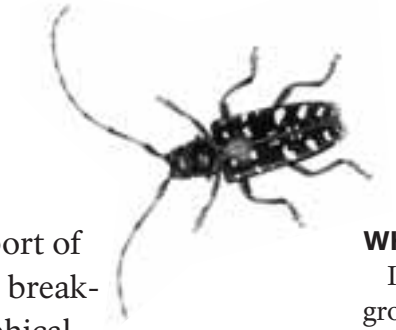
THE CHALLENGE OF EFFECTIVELY ADDRESSING **THE THREAT OF INVASIVE SPECIES** TO THE NATIONAL PARK SYSTEM



By Lloyd Loope

Ever-increasing transport of species of all kinds is breaking down biogeographical boundaries with profound consequences for biodiversity loss worldwide (Vitousek et al. 1997, Mooney and Hobbs 2000). When species are transported—intentionally or inadvertently—outside their original geographic ranges, many of them become established and spread. Some proliferate explosively, tending to displace native species in their new area of establishment. Evolving technology (e.g., containers) has increased shipping speeds and volumes, making our detection and interception strategies for stemming the flow of invasives in the United States very difficult to implement and certainly inadequate (Campbell 2001; Loope and Howarth 2003) (fig. 1). Given the seeds of catastrophic loss already planted and those yet to come, invasive species pose a highly significant threat to the biodiversity of the U.S. National Park System in the early decades of the 21st century (e.g., Wilcove et al. 1998). Moreover, global climate change is likely to exacerbate the problem by favoring invasive nonnative species over native species (Mooney and Hobbs 2000). Writing as a former (24 years) employee of the National Park Service, now with the U.S. Geological Survey (USGS), my attempt here is at a personal review and synthesis of implications of trends in biological invasions for national parks, based on personal experience and analyses by others.

WHO WILL PREVENT AND COMBAT INVASIONS?

Invasive plants comprise a highly visible taxonomic group among many serious biological invaders permeating the United States and reaching even the relatively isolated and intact ecosystems of the national parks. Federal natural resource managers can potentially address invasive species issues in conjunction with local outreach efforts, working with agencies (federal, state, and local) and individuals in communities surrounding the parks and refuges for education, prevention, detection, and rapid response.

An NPS workshop in Ft. Collins, Colorado, 4–6 June 2002, in which I participated, produced useful guidelines for monitoring invasive plants in and near the national parks (Hiebert and others 2002). Noteworthy innovations of the guidelines include the need to "work outside of park boundaries to manage at a landscape scale … [and] identify a buffer zone, which, when adequately managed in cooperation with partners, will more effectively accomplish invasive species management goals." Yet, although increasing attention is being given by public and private entities to the need for controlling plant inva-

Figure 1. Containers arrive at the Port of Auckland, New Zealand. The New Zealand Ministry of Agriculture and Forestry (www.maf.govt.nz) is at the forefront of exploring techniques for reducing the risk of pest introduction via the burgeoning sea and air container traffic, a primary factor leading to rampant biological invasions worldwide. USGS PHOTO BY PHILIP THOMAS; INSECT ILLUSTRATION—USDA FOREST SERVICE

sions, almost no barriers to the movement of plant species by humans throughout the world exist, including the United States. Approximately 20,000 species of vascular plants have proved invasive and damaging somewhere in the world (Randall 2002). U.S. federal noxious weed law (APHIS 2000) currently prohibits 91 species and five genera, most of which are well-documented threats to agriculture.

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Other taxonomic groups besides vascular plants pose present and even greater future threats to park ecosystems. Insects and fungal diseases that attack trees are probably the most important groups nationwide. The Forest Service began working with the Animal and Plant Health Inspection Service (APHIS) of the U.S. Department of Agriculture (USDA) in the late 1980s to address invasive species threats associated with raw wood imports and solid-wood packaging materials (e.g., Tkacz et al. 1998). Nevertheless, Thomas Hofacker (staff entomologist, USDA Forest Service) sees forest health in the United States as broadly declining, with three to five new problematic insects or pathogens becoming established in this country each year, and with many tree species becoming "functionally extinct" (presentation at annual meeting of Entomological Society of America, San Diego, CA, December, 2001). Campbell (2001) believes this situation is at least partly because the international system for regulating trade to prevent transport of potentially harmful organisms places a huge burden of proof on countries wanting to protect their ecosystems from pests arriving through such pathways as raw wood and wood packing materials. Another important point is that the national and international quarantine system was designed to protect mainstream agriculture with little or no reference to the protection of natural areas from biological invasions (Campbell 2001, Baskin 2002).

In the United States, the agency primarily responsible for protecting our nation's borders from biological invasions was until recently USDA-APHIS. Because of growing recognition of the need to address this problem (e.g., the threat to forests of insects and diseases in raw wood and wood packaging material) and others, APHIS had begun to focus beyond its primary mandate of protecting mainstream American agriculture. Most of the large branch of APHIS responsible for protecting our borders from biological invasions at U.S. ports of entry (Plant Protection and Quarantine) was transferred to the Department of Homeland Security (DHS) in March 2003. How this move to a different government department with a different mandate will affect the protection of natural areas and biodiversity is not clear.

A 1993 report by the Congressional Office of Technology Assessment recognized many challenges the existing system faces to keep harmful nonindigenous species out of the United States (OTA 1993). For example, first-class mail within this country is a virtually unaddressed major pathway for transport of biological material (potentially, for example, federal noxious weeds), protected against "unreasonable searches" by the Fourth Amendment to the U.S. Constitution (OTA 1993, p. 48–49). This is just one of many cases cited in the OTA report in which the current system gives invaders the edge.

Since publication of the OTA report, international treaties to facilitate the workings of the multilateral trading system have evolved (Werksman 2004). After years of trade negotiations, the World Trade Organization was established in 1995 and with it a treaty on sanitary and phytosanitary measures (FAO 2004). The treaty is managed by the Food and Agriculture Organization of the United Nations, which is responsible for implementing the International Plant Protection Convention. Some of the trade-promotion measures have not benefited invasive species prevention. For example, countries cannot legally exclude a potential pest in commerce unless they can clearly establish that a specific, credible threat exists through a risk-assessment process. Moreover, a country can require *only the minimum* treatment measures documented as effective in reducing risk. On the positive side, it can be said that the international system has responded well to the threat of movement of pests in solid-wood packaging material and has produced largely excellent guidelines for regulating this pathway (FAO 2002)

BIOLOGICAL ASYMMETRY AND INVASIONS

Not all regions of the world are equally susceptible to biological invasions; some regions primarily seem to be source areas. Called biogeographic asymmetry, this phenomenon has been widely recognized in marine and aquatic invasions (Vermeij 1991, Lodge 1993) although it is just as prevalent in terrestrial invasions. North American forests are particularly vulnerable to invasions of European and Asian insects (North American Forest Commission 2000) (fig. 2). Many more plant-eating forest insects from Europe have successfully invaded North America (approximately 300) than have invaded Europe from North America (34) (Nemiela and Mattson 1996). The decline of forest species of eastern North America caused by insects and pathogens, mainly from Asia (Campbell and Schlarbaum 2002), does not seem to be a reciprocal phenomenon. Very few native insects and diseases of North America are known to have become established in Asian forests.

HAWAII—THE U.S. REGION MOST SUSCEPTIBLE TO BIOLOGICAL INVASIONS

Oceanic islands are well known to be especially vulnerable to invasive species. The Hawaiian Islands comprise one of the most isolated island groups in the world, with biological endemism at the species level approaching 100% for many native groups. Over all, Hawaii has approximately 10,000 endemic species (found nowhere else on Earth besides Hawaii), out of a total biota of approximately 20,000 native species (Eldredge and Evenhuis 2003). Hawaii, with far above-average vulnerability to invasions (Loope and Mueller-Dombois 1989), is also a major international hub of commerce. It is by far the U.S. region most damaged by invasions, with large numbers of and serious impacts from invasive vertebrates, invertebrates, and flowering plants (e.g., Loope 1998).

Figure 2. The destructive Asian longhorned beetle *(Anoplophora glabripennis)* from China provided a wake-up call regarding the threat of solid-wood packaging material as a major pathway for invasive pests into the United States. After being intercepted repeatedly at ports of entry for several years by border protection quarantine officials, a population was discovered in Chicago in 1998. USDA FOREST SERVICE

Nevertheless, Hawaii receives no special protection to prevent invasive species introductions. Border protection from foreign passengers' baggage and cargo at the Port of Honolulu is essentially identical to that at all other international ports in the United States (CFR, Chapter 7, 319.56-8). Preventive actions are taken based primarily on an approved list of organisms for which specific legal authority is deemed to exist (James Kosciuk, Agriculture Liaison, Customs and Border Protection, DHS, Honolulu, Hawaii, personal communication, May 2004). Moreover, although Hawaii has better laws for preventing invasive species establishment than most states (OTA 1993), the Hawaii Department of Agriculture has little or no authority for protection from pests from foreign sources and receives limited funding (HDOA 2002). USDA-APHIS has a large program based in Hawaii for airport departure inspections to protect mainstream agriculture on the U.S. mainland from Hawaii's pests but no reciprocal measures for protecting Hawaii (OTA 1993). Clearly, the quarantine system is not protecting Hawaii from what Bright (1999) termed the "pathogens of globalization."

Hawaii has been one of the most unfortunate locations in the world as far as pest introduction is concerned, and its biodiversity and agriculture have suffered. The state is in the midst of an invasive species crisis affecting not only the archipelago's highly endemic biota, but also overall environmental and human health, and viability of its tourism- and agriculture-based economy (CGAPS 1996). The Invasive Species Specialist Group of the World Conservation Union (i.e., IUCN) recently developed a list of "100 of the World's Worst Invasive Species" (ISSG 2002); Hawaii has 47 of them.

Hawaii has roughly the same total number of nonnative arthropod species as the continental United States. McGregor (1973) speculated on the reason: "Although there is much greater diversity of crops and habitats within the continental United States, these are dispersed over a vastly larger land area. In Hawaii, where the overall diversity is less, the various habitats are more readily accessible from the principal port of entry." The more moderate and stable climate of Hawaii is also more favorable to an invading species than the climate in much of the United States. Furthermore, McGregor (1973) recognized this point in relation to agricultural quarantine: "(for insects and mites) in the period 1942–72 the rate of colonization per thousand square miles was 40 species, 500 times the rate of [the] continental United States." There is no evidence to indicate that this pattern has changed in the following 30 years.

More native species have been eliminated in Hawaii than anywhere else in the United States. Hawaii has lost about 8% of its native plant species and an additional 29% are at risk (Loope 1998). The state has lost 27 of its 73 historically known bird species and about 900 of 1,263 described land snail species (Loope 1998). With just

0.2% of the U.S. land area, Hawaii has about 30% of U.S. endangered species. Although habitat destruction has been an important cause of extinction and endangerment, the introduction and spread of invasive alien species has contributed in a major way in the past and is now the predominant cause of biodiversity loss in Hawaii.

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Still, much biological richness is left in Hawaii's national parks, mostly at high elevations, but what is left is threatened by old, new, and future invasions. The invasive tree *Miconia calvescens* is an alarming and imminent threat (fig. 3). This large-leaved, shade-tolerant tree from tropical America has greatly reduced biodiversity over most of the rain forest area of Tahiti (Meyer 1996, Meyer and Florence 1996) and promises to do the same in Hawaii without major management intervention. Hawaii's national parks and Hawaii's NPS Exotic Plant Management Team are very much involved in interagency efforts to manage *M. calvescens* (e.g., Loope and Reeser 2001).

Good models for improved prevention for Hawaii exist in the largely successful preventive systems in place in New Zealand and Australia. In these countries the public accepts laws and procedures, some involving a small loss of personal freedom, as the price that must be paid for protecting agriculture, forests, and native ecosystems. New Zealand has comprehensive biosecurity legislation and a highly rigorous border control system, utilizing trained dogs and X-ray technology (Baskin 2002, Loope 2004). Australia has a relatively successful plant screening system that has evaluated thousands of new plant introductions since its inception (Pheloung et al. 1999, Baskin 2002).

Figure 3. Biologist Jean-Yves Meyer stands beneath a typical forest of the invasive tree Miconia calvescens in Tahiti. Miconia has become recognized as an invader capable of extinguishing biodiversity in island rainforests, and is being aggressively combated by the Hawaii Exotic Plant Management Team and others in Hawaii. PHOTO COURTESY OF JEAN-FRANÇOIS BUTAUD AND JEAN-YVES MEYER, 2004.

The stakes are high in Hawaii because of the state's world-class biota. No location in the world rivals Hawaii as a showcase for biotic evolution in isolation and adaptive radiation—not even the famed Galapagos archipelago (Williamson 1981). In Hawaii, the National Park Service emerged as a leader in conservation biology about 1970, turning apathy into action, and showed that extensive native ecosystems persisted at high elevations in the state. It has pioneered the use of fencing as a tool for sustained elimination of feral ungulates (Stone and Loope 1996), serious alien plant control within designated "special ecological areas" (Tunison and Stone 1992), pushing for better quarantine measures at airports and harbors (Reeser 2001), and drawing the line against *Miconia* and other invasive species. The National Park Service in Hawaii is well aware that it cannot rest on its laurels, however (Bryan Harry, NPS Pacific area director, personal communication, 2004).

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LAG TIME OFTEN MASKS BIOLOGICAL INVASIONS ON THE U.S. MAINLAND

Given unabated action of similar forces responsible for continued ecological degradation—habitat destruction and fragmentation, biological invasion, and cascading effects—biodiversity of mainland national parks is clearly at risk (Vitousek et al. 1997). Meanwhile, Hawaii comprises a useful testing ground where strategies to prevent and combat invasions can be applied, tested, and refined.

Lag time is an important and underappreciated phenomenon in invasion biology and tends to mask the pervasiveness of invasive species on the North American continent. For example, very many nonnative insect and disease problems in eastern North America went unnoticed initially but have gathered momentum and become acutely problematic with time. For example, white pine blister rust (*Cronartium ribicola*), introduced with nursery stock from Europe, has been in this country for more than a century (Maloy 2001), but it is just now killing most of the whitebark pine (*Pinus albicaulis*) trees in the northern Rocky Mountains from Glacier National Park to Yellowstone and Grand Teton.

Likewise, hemlock woolly adelgid *(Adelges tsugae),* a tiny insect, also illustrates well the case of serious invasions, which are revealed as serious only gradually. Native to Asia, it reached the western United States in the 1920s and the eastern part of the country in the 1950s, but the conventional wisdom was that it attacked only cultivated hemlocks (Van Driesche and Van Driesche 2000). In the 1980s, reports surfaced of eastern hemlock death in Virginia, and the infestation has now become a huge problem from New England to North Carolina and is slowly spreading westward (see article and illustrations, pages 53–56). This may be an invasion that could cause functional extinction of two hemlock species, eastern hemlock (*Tsuga canadensis*) and Carolina hemlock (*Tsuga caroliniana*).

Lag times are not always as long. Balsam woolly adelgid *(Adelges piceae)* has virtually eliminated Fraser fir (*Abies fraseri*) in Great Smoky Mountains National Park; it was first noted in the United States about 1950 and started attacking fir in the Smokies in the 1970s (see article and illustrations, pages 64–65). Dogwood anthracnose *(Discula destructive),* first detected in the country in the 1970s, was reducing or eliminating flowering dogwood (*Cornus florida*) in many eastern national park areas by the 1990s (Langdon and Johnston 1992).

Fast-moving and newly emergent invasive diseases deservedly get the most attention. Sudden oak death syndrome (caused by the fungus *Phytophthora ramorum*) is a high-visibility problem that popped up in 1995 in California and kills healthy trees within four months (Kliejunas 2001). For nearly a decade, the fungus in the United States had been confined to Pacific states, but its chances of invading southeastern states, where numerous potentially susceptible oak *(Quercus)* species are ecological dominants, was learned to have been hastened in early 2004. At that time it was found that in spite of the best preventative efforts of APHIS, one large, infected nursery in Los Angeles had shipped susceptible plant material widely. An APHIS update reported, "As of June 15, *P. ramorum* has been confirmed in plants traced forward from the initially positive Los Angles County wholesaler at 118 sites in 16 states," including 11 states in the southeast (APHIS 2004).

How many more sleeper invasions have already been inoculated within ecosystems worldwide by the recent burgeoning of trade—involving diverse pathways from solid-wood packing and raw lumber to seed trade on the Internet? And how much are protective systems going to improve in the coming decades in addressing continuing inoculations? In my view, change is going to depend more than anything on awareness.

WHO WILL TELL THE PEOPLE?

Entomologists Nemiela and Mattson, in a 1996 article in *BioScience*, stated (p. 751): "When the outrageous economic and ecological costs of the wanton spread of existing exotics and continued entry of new ones become common knowledge, it is inevitable that there will be a public outcry for actions to mitigate the potentially dire consequences." Whose responsibility is it to inform the public?

One might conclude that the seriousness of the problem of biological invasions seems to be largely unrecognized in the consciousness of the American public. Among environmental concerns, clean air and clean water perhaps understandably seem to attract the most attention (since their direct effects are readily imagined). The reality is that biological invasions threaten much more than the integrity of natural ecosystems of national parks. They pose immense threats to the U.S. economy, agriculture, and forest resources, and to the public health and quality of life of U.S. citizens. Yet it seems that almost nowhere in American society is this message being conveyed effectively. Admittedly, the press reports with high frequency on specific invading species, but only rarely produces in-depth analyses relevant to the general problem of invasions (e.g., Nash 2004, Choo 2004).

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HOW CAN THE NATIONAL PARK SERVICE RISE TO THE CHALLENGE?

The issue of the threat of invasive alien species to natural areas obviously presents huge challenges, but there are many possibilities for working toward "solutions." A

recent issue of *BioScience* presents an upbeat mix of ideas on promising approaches by knowledgeable scientists (Dybas 2004). One such scientist's (Daniel Simberloff) presentation was entitled "We can win this war: The dangers of pessimism about introduced species." Another (David Lodge) is quoted as having made the observation that screening species for invasiveness is one of the essentials and that "we have or are developing the tools to do that. The management and policy tools, however, lag way behind." A third scientist (Ann Bartuska) expressed frustration over "how little we have done about dealing with … [the invasive species issue]—given how big it is, how clearly we know the impacts, how widespread it is, and how it touches everyone in one way or another.… We seem to have the political will and the public will to really take on fire [in wildland management] in a big way … but we don't seem to be able to do the same with invasive species." Her suggested solutions included "integrated vector management" and "an effective early detection rapid response system."

The National Park Service has special incentives for ramping up its efforts to address the invasive species issue. National parks and their ecosystems provide an excellent opportunity to bring the invasions message to the U.S. public. Parks have been identified in the past (originally by NPS Director George Hartzog in the early 1970s) as "miners' canaries" for U.S. environmental health and indeed can well serve as such for communication of the invasions message. Some regions and parks are much more susceptible to invasions than others, with some already showing substantial degradation. Parks in Hawaii, California, and Florida are especially affected by invasions. Those parks provide unfortunate but strong lessons to be learned by NPS employees and the general public. Those fortunate regions and parks that have up to now been less susceptible and have largely escaped damage by invasions can learn from their neighbors and anticipate threats posed by future invasions.

The 1916 NPS Organic Act states clearly that the national parks are to be kept "unimpaired for the enjoyment of future generations." The National Park Service now appears to be faced most ominously with massive impairment of the parks' natural resources by biological invasions from outside. One role for the National Park Service might be to accelerate its proactive role in informing its employees and the American public of the insidious nature of biological invasions. Another might be to include serious analyses of the importance of proactive quarantine systems suitable for regions at risk such as the Hawaiian Islands (see Reeser 2002). Major breakthroughs in science, policy, and management will likely be needed to address the complex and important issue of biological invasions if substantial impairment of the parks is to be averted.

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